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## PORTO RICO AGRICULTURAL EXPERIMENT STATION,

D. W. MAY, Special Agent in Charge.

Mayaguez, November, 1906.

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## FERTILIZERS,

BY

D. W. MAY,

*Special Agent in Charge.*

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UNDER THE SUPERVISION OF  
OFFICE OF EXPERIMENT STATIONS,  
U. S. DEPARTMENT OF AGRICULTURE.

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## PORTO RICO AGRICULTURAL EXPERIMENT STATION.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations,  
United States Department of Agriculture.]

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[Cir. 6]

# FERTILIZERS.

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## INTRODUCTION.

The base of all agricultural practise is the soil; upon the capacity and proper management of soils all success in agriculture primarily depends. The plant secures from the soil and the air some fifteen different elements—from these it adds to its growth. By a chemical analysis we find what different elements plants contain and the amounts, as lime, iron, nitrogen, phosphorus, etc. From studies made during the last one hundred years it has been found that of the different substances going into the composition of plants, the three which are most likely to be deficient in average soils are nitrogen, phosphorus, and potash. Soils may be benefited by the addition of other elements, as lime, but it is believed to be due more to their physical action than the fact that the plant actually needs more of such elements than are already available in the soil.

In general a fertilizer may be said to be anything that improves the capacity of the soil to grow plants. A fertilizer may do this by, first, adding to the soil an element that is lacking and that is needed by the plants; or second, by improving the physical condition of the soil so that plants may take therefrom certain elements that are thereby rendered available. Moreover, certain fertilizers contain small organisms known as bacteria, which set free in the soil elements needed by the plant. It is largely for this reason and because of the decaying vegetable matter in it which improves the physical condition of the soil that manure makes one of the best fertilizers.

Porto Rico is one of the older settled portions of the Western Hemisphere; moreover, it has sustained for many years a very dense population. The island has produced many crops that have drawn heavily upon the soil, so that now agriculture presents many of the problems of handling an abandoned farm. The great mistake made in agricultural practise in Porto Rico has been in the continued cropping of soils without adding anything thereto.

A field of the experiment station will exemplify the usual practise here. This piece of land has been cropt for perhaps two hundred years; cane has been taken from this field as long as it would produce cane and then it has been allowed to grow up in malojillo grass and

this crop cut and sold off the place in the near-by town. A former owner told the writer that during his occupancy sixteen crops of cane were taken from this field one year after another. Considering such treatment, is it any wonder that the fields of Porto Rico are depleted and a great many of them abandoned?

What then is the first duty of the agriculturist in Porto Rico—indeed, what is the prime necessity? It is to bring back to the land some of the old-time fertility which gave to the island the name Porto Rico—rich port.

The elements of plant food most likely to be needed in soils are nitrogen, phosphorus, and potash. Very poor soils, like most of those found in Porto Rico, need all three of these, and in many instances lime also. Therefore, in improving the soil we must seek out and apply especially all the nitrogen, phosphorus, and potash that we can find. Upon the application of these to our fields depends the future prosperity of the island. Let us then look to the sources from which we can obtain these elements of fertility.

#### NATURAL MANURES.

The first of these to command our attention is the supply of manure. This will in nowise meet the requirements, yet the amount available is now largely wasted. Take the city of Mayaguez as an example. Manure is given to any one that will haul it, and yet large amounts are allowed to be leached by the rain and dissipated by the sun in piles about the stables, proving a nuisance to the town and of no benefit to the country. In sections where agriculture is more advanced such manures sell readily, the buyer not only removing it from the stables and lots, but paying a substantial price for it. Happily its value is becoming realized and some planters are hauling it, and even shipping it long distances along the coast, from towns to their plantations. This material proves of great benefit to our fields, not only from the fact that it yields nitrogen, phosphorus, and potash, but also humus, which greatly improves the physical condition of the soil, rendering it more porous, permitting plants to extend their roots more readily and to take up more plant food. The manure produced by horses has been estimated to be worth \$27 per head for one year, for cattle \$19, and for hogs \$12. This value, of course, depends upon the character of the feed consumed by the animals. Its value also largely depends upon the method by which it is handled. If convenient to do so, manure should be immediately hauled and spread upon the land and, better, plowed under. If this is not possible, it should be stored in pits and kept reasonably moist until well rotted. The value of manure, estimated on the amount of nitrogen, phosphorus, and potash it contains, will vary from \$2.50

to \$4 per ton. This will give some idea of the money thrown away in the ordinary wasteful method of handling manure in Porto Rico. If malojillo grass is sold from a farm it will rapidly deplete the fertility of the soil, but if the farmer, when he sells a load of malojillo, will return with a load of manure he will increase the fertility. In selling our products from the farm we should bear in mind that we sell fertility in a greater or less degree, and in buying fertilizers we are buying back in part what we have sold. If we feed more of our products on the farm to our live stock we are returning to the land the fertilizing elements taken from it.

A ton of mixt pasture grasses contains 18 pounds of nitrogen, 4.6 pounds phosphoric acid, and 15 pounds potash. The value of these elements as we purchase them back, estimating nitrogen at 15 cents per pound, phosphoric acid at 5 cents, and potash at 5 cents, would be as follows per ton:

<i>Fertilizing value of grass per ton.</i>	
Nitrogen.....	\$2.70
Phosphoric acid.....	.23
Potash.....	.75
Total.....	3.68

Another valuable substance available to Porto Rican planters for fertilizing the soil is tobacco stems and waste from the cigar factories. This substance is particularly rich in potash. Tobacco stalks contain 3.7 per cent nitrogen, 5 per cent potash, and 0.65 per cent phosphoric acid.<sup>a</sup> The stems contain less nitrogen and more potash. Such refuse is at fertilizer prices worth about \$15 per ton. Besides improving the physical texture of the soils, tobacco waste has a value as an insecticide, having a tendency to keep insects out of the soil. All tobacco stems and waste should be carefully preserved and used for improving our soils. At present these materials can be secured at very low prices and the enterprising planter will secure all that it is possible for him to obtain at fair prices.

Lime is found in varying amounts in all plants and is necessary to their growth. It is found in all soils and usually in amounts sufficient for the direct needs of the plant. It is, however, often needed on soils that have become acid, for the purpose of rendering them sweet and improving their physical condition. It not only renders them more friable, especially clay soils, but it apparently has the effect of rendering certain plant foods more available. A great many of our Porto Rican soils need lime, especially lowlands and those that are poorly drained. The larger cane growers on the island are using a great deal of lime on the poorer lands especially. The benefits are very pronounced and it is a good practise to follow in many instances. The

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<sup>a</sup> U. S. Dept. Agr., Office of Experiment Stations Bul. 15, p. 408.

form of lime usually employed is burnt lime, known as quicklime. The price in the island varies with localities and ranges from \$5 to \$7 per ton.

There is in many sections a soft limestone found, more especially in the first range of hills from the seacoast. These deposits are probably of sea formation, and the lime as it comes out of the earth is soft and may be cut with a spade. From analyses the station had made these limes run over 50 per cent calcium oxid ( $\text{CaO}$ ). From preliminary experiments made with this material it seems that it is a valuable substance to use for liming soils. Where it is convenient planters are recommended to try using it on land in comparison with other portions where it has not been applied. In this way its value can be very quickly determined.

In many parts of the island caves are found containing deposits of bat guano. Many of these deposits are quite valuable, being especially rich in phosphorus. Wherever these guanos can be obtained planters are advised to try them, starting with small amounts and comparing the results with crops where none has been applied.

Ashes, especially the unleached hardwood ashes, are an important source of potash, the latter running over 5 per cent of this element and containing some phosphorus. Where ashes are old and have been leached by the rains they are of little value, but fresh wood ashes should be applied to the land immediately after burning, and from them good results may be expected.

There are several other sources from which small amounts of manurial substances may be obtained on the farm. It is a good practise to have a pit or protected place where refuse from various sources may be dumped. Such a place is known as a compost heap and may contain residues of different plants, ashes from the kitchen, and waste materials that usually accumulate about a house. It is well to add lime to these materials, as it increases the value and induces decay.

#### COMMERCIAL FERTILIZERS.

After utilizing all the natural resources from which we may obtain the fertilizing elements it is necessary and advisable that Porto Rico buy commercial manures. The success of agriculture in the island undoubtedly rests upon the proper employment of fertilizers, and as we are only beginning to use them in any amount it is well that certain principles underlying their purchase and use be set forth. While success will depend upon the proper fertilization of our soils, at the same time a great deal of money can be spent on artificial manures that will not yield an adequate return. The planter should learn first of all and keep in mind the fact that in purchasing fertilizers he is not paying so much per ton, but so much per pound for the nitrogen, phosphorus, and potash contained therein. This is well recognized in countries

where fertilizers have been used for some time and no consideration is had for the other portions of the fertilizer, or of the fillers, as they are called. It has been sought to reckon a price for the three elements at so much per pound, and the value of a ton of fertilizer depends upon the number of pounds multiplied by the price per pound. The prices of nitrogen, phosphorus, and potash vary, as do other marketable products, depending upon the factor of supply and demand. At present nitrogen is worth in the neighborhood of 16 cents and phosphorus and potash 6 cents each per pound. A fertilizer containing all three of these elements is called a complete fertilizer, and all those sold in Porto Rico at the present time are of this kind. The legislature has past an act requiring the fertilizer manufacturers to place upon each bag containing their goods the percentage of nitrogen, phosphorus, and potash, so that the buyer will know the amount of these elements that he is getting. If the buyer has any doubt about these fertilizers containing the amount guaranteed he can have a sample analyzed by the commissioner of the interior and the manufacturer's guaranty tested without charge.

#### NITROGEN.

Of the three elements that form the basis of value for a fertilizer nitrogen is the most expensive, costing approximately 16 cents per pound. This one element is represented by the symbol N. One part of nitrogen and three parts of hydrogen make ammonia. This chemical combination is of value simply for the nitrogen it contains. The greatest source of nitrogen at the present time is the nitrate deposits of Chile and Peru. As this district receives no rain the nitrogen is not washed out as it is in other countries. The amounts of this material mined and shipped are enormous, and it is probable that in the course of a few decades the supply will be exhausted. Besides being used for a fertilizer this nitrate is also extensively used in the manufacture of gunpowder and for other purposes.

The air consists of a mixture of four parts of nitrogen to one part of oxygen. This would apparently indicate that plants do not need nitrogen in the soil, but it is a fact that with few exceptions plants are not able to secure nitrogen from the air. It has long been known that certain plants belonging to the family known as legumes enrich the soil upon which they grow. In this family belong peas, beans, clovers, and a number of trees, as the guama, flamboyan, etc. As many of these leguminous plants will grow in Porto Rico, and at any season of the year, it is not a wise policy to buy nitrogen for slow-growing, and especially the less profitable crops, when it can be so easily produced. It is only in the case where very profitable crops are desired quickly that any amount of this element should be

purchased. In our fields nitrogen can be produced with beans especially. These can be grown in the rows or they can be grown as separate crops when the other crops do not cover the ground. In the coffee plantations nitrogen can be produced by growing leguminous shade trees, as the guama. This tree is especially valuable as shade for coffee, due to the fact that it is a nitrogen producer. It is therefore advisable to plant as shade for coffee only leguminous trees, of which there are several found in Porto Rico.

It is known that leguminous crops are able to store nitrogen in the soil by means of bacteria, small organisms that grow in nodules on the roots of these plants. It has been found that leguminous plants without these nodules do not secure the nitrogen from the air, while on the contrary those that do have nodules are able to secure it from this source. It is sometimes found that a legume new to a certain section will not store nitrogen because of the absence of the nodule-forming bacteria. In such cases it is therefore necessary to inoculate the soil with this bacteria. These inoculating organisms are found in soils where a certain leguminous crop has been grown for some time, and a new field planted to legumes may be inoculated by scattering a small amount of soil taken from a field in which that same legume has been growing and producing nodules. The seeds may also be inoculated before planting by sprinkling them with a thin watery solution of soil from an inoculated field.

Nitrogen is a stimulating manure and is best applied at the beginning of a crop or before. If it is in organic form it should be allowed time to rot or ferment, for only then is it available to the plant. When it has been produced by leguminous plants, like beans, it should be plowed under and allowed some time to decay before the new crop is planted. It will start crops off to growing very quickly, but it should usually not be applied during the fruiting season, as there is a tendency to induce further growth and not fruit. Applied late on cane fields it has a tendency to produce a large immature cane with a low sugar content.

There is a great rivalry among the manufacturers as to the superiority of the different forms of nitrogen that they produce. The real question in any case is as to the availability of the nitrogen and the changes necessary to render the nitrogen readily available to the plant. This varies somewhat, but not greatly, with the soil and with the plant itself. One purpose of fertilizer inspection in the island is to determine whether the nitrogen content of a fertilizer is in an available form. If a fertilizer is not composed of leather, horns, and hoofs, such as is prohibited by the Porto Rican law, then the nitrogenous materials should very quickly decay when applied to the soil.

## PHOSPHORUS.

From studies made by the various experiment stations, phosphorus is the element that is most generally needed on our soils. This element is said to be the backbone of American agriculture. It is this element which limits the capacity of the larger areas cultivated within the bounds of the United States. We obtain phosphorus from by-products of several lines of manufacture. One of the greatest sources of phosphorus is bone. This material is gathered up about the country or it is secured from the packing houses where large numbers of animals are annually slaughtered for food. We also obtain phosphorus from basic slag, a by-product of the iron mills rich in phosphorus. This material is finely ground and added to the soil. These by-products provide only a small part of the needs of our soils for phosphorus. The phosphate mines in South Carolina, Florida, and Tennessee produce the largest amount of phosphorus that is now used. These mines were once thought to be inexhaustible, but at the present rate of removal they will be exhausted within a century. At the present time 1,500,000 tons of phosphate rock are removed annually. Of this the larger part is now exported. To render it more readily available phosphate rock is treated with sulfuric acid. This enables plants to take it up more readily, but from recent experiments it is doubtful if this is profitable except when the phosphorus is needed immediately. Wherever phosphates are finely ground, they are soon assimilated by the plants, and it is far more economical to buy the finely ground phosphate rather than the acid phosphate.

Before buying any large amount of phosphorus it is advisable in Porto Rico to first use the supplies available in the island. Besides the manures and waste products, as tobacco stems, there are many large deposits of guanos found in the caves of the island, which are often very rich in phosphorus. These may be applied as they are dug out of the cave and do not need to be treated with sulfuric acid. Wherever these deposits are available, it is advisable that an analysis be made and that they be used wherever their transportation will justify. Phosphorus is needed during the entire life of the plant, and as it is not volatile in the air and is not readily washed out of the soil, it can be applied in larger amounts than nitrogen with little danger of loss.

## POTASH.

This is an element of which the natural supplies are somewhat limited. The greatest deposits of potash are found in the Stassfurt mines of Germany and large amounts are shipped all over the civilized world. These potash salts are sold in their natural state as kainit and other forms, containing more or less impurities and running about

12 to 15 per cent of potash. They are also sold in more concentrated forms, as sulfate and muriate. These run about 50 per cent potash. As we must import practically all of our potash, it is advisable to buy the more concentrated forms, as sulfate and muriate. Sulfate costs slightly more than muriate, but it is preferable to use on some crops. For example, the chlorin in the muriate of potash is believed to be bad for tobacco, affecting especially the burning quality of the leaf.

### FERTILIZERS FOR PORTO RICO.

The planter is advised to use first of all the materials available, as stable manure, bat guano, tobacco stems, ashes, etc. As to whether he should buy ready-mixt fertilizers or buy the elements separately and mix them is a question he must decide for himself. Above all things it should be remembered that it is not the price per ton that he should estimate, but the price per pound of nitrogen, phosphorus, and potash that that ton contains. This is the true basis of its value, and besides these elements the remainder of the fertilizer is simply a filler. It will be noted that many of the mixt fertilizers contain very small percentages of some of the elements. In Porto Rico we should not buy a low-grade fertilizer. The freight on a low-grade fertilizer is the same as on a high-grade one, and it makes no difference how much nitrogen, phosphorus, and potash are contained, freight charges are always the same; therefore the planter should buy high-grade goods.

### VALUE AND COST.

A great many of the ready-mixt fertilizers are on the market in Porto Rico. If the planter buys much of these he should send samples to the commissioner of the interior to be analyzed to see if they come up to the guaranty stamped on each bag required by law. If they do not come up to the guaranty he has recourse against the company.

We can not undertake to place a value upon the fertilizer. This the buyer must determine for himself. The law requires the manufacturer to state how much nitrogen, phosphorus, and potash his goods contain. The buyer then can tell by a simple problem in division what these elements are costing him per pound and can therefore compare the value of one fertilizer with another. He can also get quotations of potash, phosphorus, and nitrogen in the different forms offered for sale and can then determine whether it is cheaper for him to buy his fertilizers ready mixt or to buy the elements separately and mix them himself, which process is not necessarily a complicated affair. For example, a ton of nitrate of soda quoted at \$48 per ton is guaranteed to contain 15 per cent of nitrogen. Fifteen

per cent of 2,000 pounds, or 1 ton, is 300 pounds of nitrogen. If 300 pounds of nitrogen cost \$48, 1 pound will cost 16 cents. Acid phosphate containing 14 per cent of phosphoric acid and costing \$14 per ton will mean that that substance is worth 5 cents per pound. And so with potash—a sulfate containing 50 per cent of this element, costing \$50 per ton, will show that potash is worth 5 cents per pound. By looking up the market quotations the price of a single element of a fertilizer can be determined at any time. In buying a fertilizer already mixt the planter saves something in labor. Buying them singly and mixing them himself he is more apt to study the real needs of the soil.

There are two systems of purchasing fertilizers. One is called the unit basis, and in this case the quotations are priced or based upon the percentage of elements contained in the fertilizer; or, in other words, the amount of nitrogen, phosphorus, and potash is estimated at so much per pound. This method is a most satisfactory one to both the dealer and the consumer. The consumer receives exactly what he pays for and the producer is paid for what he delivers. The amounts contained in the fertilizer are determined by chemical analysis and are approximately correct. The other method is on the ton basis of purchase and is a very fair method where the goods involved are high grade and are made of products that run uniformly alike in analyses. In this case the ton is accompanied by a guaranty which warrants the goods to contain certain percentages of the elements desired.

It should be noticed that guaranties are sometimes stated in different ways, as nitrogen may be estimated as ammonia, or phosphorus as phosphate of lime. The best way is to estimate these materials not as a combination but as elements. Ammonia is a combination of nitrogen with hydrogen; bone phosphate is simply a combination of phosphorus with lime and other things. Ammonia contains 82 per cent nitrogen; bone phosphate 46 per cent phosphorus.

The cost of the cultivation of a crop is the same whether we use fertilizers or not. With this in view, then, the use of fertilizers is made with the idea of securing over and above cost of materials purchased a sufficient increase in the crop to make an added profit. The planter must decide for himself whether to use fertilizers, and if so, how much. It is very evident that fertilizers do not always pay and there are several factors that determine this matter. The kind of soil will sometimes indicate the kind of fertilizer to use. As a rule potash is advisable on sandy soils, while on clay soils as a rule phosphorus is needed and also lime. These are only indications, however, and it is only by actual trials that the planter can determine best what his soils need and how much. The soils must be in good physical condition before

they can receive full benefits from an application of fertilizers. Because they are not in good physical condition is often the reason why manure does better than commercial fertilizers. Besides carrying the fertilizer elements, the manure adds the humus contained in the straw, which goes to improve the physical condition of the soils. Often green manuring—the plowing under of a crop grown on the land—will also, besides adding fertility, improve the physical condition. This is especially valuable in crops like cotton, where the soils become deficient in humus. It is a good practise to add phosphorus and potash to a leguminous crop, which will get nitrogen from the air; then by plowing under the whole crop the three elements are returned to the soil and the nitrogen has been obtained very cheaply.

#### HOW TO DETERMINE FERTILIZERS NEEDED.

The idea prevails in Porto Rico that a chemical analysis will show what a soil needs. This is only true in part, as a chemical analysis may show a certain element present and yet owing to certain combinations in the soil the plant can not secure it. By far the better way is to apply fertilizers of different composition and note the results on small portions of land. This the planter can carry out himself, and in doing it he is studying all the conditions that influence his particular farm and crop. A scheme of this kind is now under trial at the experiment station. A portion of a field is divided into a series of ten twentieth-acre plats.

These plats are fertilized as follows:

##### *Scheme of plats for fertilizer experiments.*

- No. 1. Nothing.
- No. 2. Nitrate of soda, 8 pounds, equal to 160 pounds per acre.
- No. 3. Acid phosphate, 16 pounds, equal to 320 pounds per acre.
- No. 4. Muriate of potash, 8 pounds, equal to 160 pounds per acre.
- No. 5. Nothing.
- No. 6. Nitrate of soda, 16 pounds; acid phosphate, 16 pounds.
- No. 7. Nitrate of soda, 16 pounds; muriate of potash, 8 pounds.
- No. 8. Acid phosphate, 32 pounds; muriate of potash, 8 pounds.
- No. 9. Nitrate of soda, 8 pounds; acid phosphate, 16 pounds; muriate of potash, 8 pounds.
- No. 10. Nothing.

To one series of plats lime is also added to note its influence on the crops. It will be noted that these amounts are rather large, larger in fact than the planter will use in general practise, but they are made so in order that the indications may be plain. The planter should take notes of the condition of his plats from time to time, and by this means he can soon see what his particular soil and crop will need, and from the harvest from the crops on these small areas he can form some idea as to profit or loss. Such experiments will save large sums

to the planter who is going to use fertilizers in any amount, and, moreover, it will teach him to observe and to follow a more rational scheme of agriculture. In applying fertilizers they should be broadcasted and harrowed in for small grains that stand close upon the ground. For cane they should be applied in the hill as a rule, as it is a practise at present in Porto Rico to use small amounts, and they should be so placed that the plant will get the greatest benefit from them without reference to the crops that are to follow. The fertilizers not only diffuse themselves thru the ground, but the roots of the plants will seek out the fertilizers. It is advisable on hill lands to bury the fertilizer to guard against leaching by the rains, to which many of our soils are quite subject. In fertilizing coffee, especially where it is on a rather steep hillside, the fertilizer should be put in a hole above the tree and covered to avoid any washing and it will then be dissolved downward toward the roots. In fertilizing fruit trees, the fertilizer should be plowed or harrowed in in the space indicated by the spread of the branches. If the ground is not subject to washing we may add phosphorus and potash in relatively large amounts, because the plants will take them when needed, but nitrogen is very easily soluble and is very liable to be leached by rain or dissipated in the air.

Some such definite scheme of fertilizing as has been outlined is far better than to follow a hit or miss plan of using a fertilizer without knowing the demands of the soil and crop. The soil may need only the one element, while the planter may be adding all three. Of course, in such cases, he is adding elements that do not make any adequate return and he is therefore making an outlay that is not justified, but by starting with small areas and using different combinations of fertilizing elements he can determine what his soils need without being liable to any appreciable loss. He can begin with the natural fertilizers, as manures, bat guanos, etc., that are within reach and use commercial fertilizers only as he finds it profitable to do so. While it is doubtless true that most Porto Rican soils need nitrogen, phosphorus, and potash, and many of them lime, yet the profitable combination is liable to vary very much, not only with different soils, but with different crops. It is found that different crops require more of one element and less of another. For example, corn requires all three—nitrogen, phosphorus, and potash—in rather liberal amounts. Other crops like the legumes, such as peas, beans, and clovers, should have phosphorus and potash and be allowed to secure their nitrogen from the air. These crops will, for about every 30 pounds of phosphorus and 100 pounds of potash, require 100 pounds of nitrogen. Of this latter they are probably getting a larger part from the air, which means clear gain of the most expensive element.

## COTTON.

If cotton growing is ever to be successful in Porto Rico, the crop must be fertilized. Phosphorus seems to be especially needed for cotton, altho it is contained in smaller amounts than nitrogen and potash, but both nitrogen and potash should be added. In the Southern States it is a practise to grow cowpeas in the cotton, thereby securing large amounts of nitrogen. As this plant grows well in Porto Rico it is advisable to plant it in rotation with cotton and plow it under. By adding phosphorus and potash to the soil for cowpeas, they will secure large amounts of nitrogen from the air and then all can be turned under for the succeeding crop of cotton. This not only adds fertility, but very greatly improves the physical condition of the soil, which is very important with the cotton crop. The fertilizer should be applied in the hill at the time of planting the cotton, and at a depth of about 3 inches.

## TOBACCO.

Tobacco is a plant of comparatively rapid growth and somewhat greedy for fertilizers. It is a very exhaustive crop, using especially large amounts of nitrogen and potash. However, in using fertilizers for tobacco, it should be borne in mind that certain kinds have a tendency to injure the quality of the leaf. This is especially true in growing cigar tobaccos. Stable manure is sometimes thought to injure the quality and to produce a rank-growing leaf; on the other hand, certain forms of potash injure the burning quality of the tobacco. This is thought to be the case with those kinds containing chlorin, as muriate of potash. The tobacco crop, being of quick growth, the fertilizers added should be readily assimilated. A good source of nitrogen for tobacco is cotton-seed meal or dried blood. Ammonium sulfate and nitrate of soda are also good. Potash should be free from chlorid, sulfate being considered better than the muriate. Phosphorus should be added in a soluble form. Tobacco is a very rank-growing crop and one that brings a very high price per acre; therefore the crop should not be stinted in regard to its food, especially as a poor crop requires almost as much labor as a good one.

## SUGAR CANE.

The sugar cane is a crop that responds very readily to the use of fertilizers. From analyses made by the Louisiana Station, 30 tons of cane will remove 102 pounds of nitrogen, 45 pounds phosphorus, and 65 pounds potash. It is therefore an exhaustive crop, and the fertilizing materials should be returned to the soil. As the product is largely shipped from the field, it will readily be seen that large amounts of fertilizers are necessary in order to restore the elements

taken away. Most of our plantations do not take the trouble to return the bagasse ashes, and they are applied by the centrals to their own fields, to the detriment of the farmers who sell the cane off their places. The cane plant is a vigorous feeder. It is able to extract the fertilizing elements from almost any kind of fertilizers. For growing cane, however, the fertilizers should be kinds that are readily dissolved.

At this station it has been found that a crop of cowpeas may be very readily grown between rows of cane. Alfalfa will also grow well, but as it is more expensive to seed, the cowpea will probably do better. After the cowpea has made a pretty good growth it may be plowed under, or the cane may be allowed to smother it. Bat guano from the caves of the island will prove very profitable for cane wherever it can be secured. A large amount of phosphorus may also be obtained from the waste material about the mill, as the bagasse ashes and the filter cake, all of which should be carefully saved and returned to the fields. While our experiments do not yet indicate the potash needs of our soils, it is probable that this is a very profitable element to add. In Louisiana the soils contain a relatively large amount of potash, and this element has not been so much needed, while in Hawaii the soils are very deficient in this element and it has been found profitable to apply very large amounts. For plant cane a small amount of soluble fertilizer should be placed in the hill in order to give the seed a good start. It is a good practise in cane growing to start the cane off quickly, as there is a chance of making a larger return. A fork full of well-rotted manure or compost in the hill at planting time has given good results at this station. Later applications of fertilizers should be made broadcast and worked in with a plow or hoe. Nitrogen should be added early in the growth of the crop, as later applications tend to make a rank growth low in sugar. Phosphorus is needed at all times during the growth of the cane, as well as potash, altho potash may be profitably added later.

#### CITRUS FRUITS.

Citrus fruits in Porto Rico require fertilizing to get good results, and in founding a citrus orchard a liberal amount should be reckoned for the purchase of fertilizers. Oranges are being planted on soils that have been cropt for many years and which are therefore comparatively poor. Under these circumstances it is necessary to add nitrogen, phosphorus, and potash. Not only are the trees more thrifty, but the time in which they will come into bearing is very much shortened. Nitrogen especially should be added in small amounts at frequent intervals. It is well to guard against too large applications of this element, as in Florida a disease called "die back" has been induced by its use. The practise now is for clean cultivation of orange groves, but this is rather

hard on the nitrogen content of the soils, as it has a tendency to render this element soluble and therefore aid in its dissipation. It is probable that a system of green manuring will work best with clean cultivation. During the dry season clean cultivation will conserve moisture in the grove, while in the wet season the green manuring will use some of the surplus moisture and at the same time store up the needed nitrogen. This is the practise that obtains among the apple growers in the States, and will probably work well here. Phosphorus may be purchased in the cheaper forms than the acid phosphate, as in fruit growing it is not so necessary that this element be in such a soluble form as with quick-growing crops. Finely ground rock phosphate can be used to advantage without paying for the expense of treatment, as with the acid phosphates. Potash can be used in various forms with fruits. As the larger amounts of potash used will have to be imported, it will be found advisable to purchase the forms that contain the largest percentages to save freight.

#### PINEAPPLES.

So far our experiments have not given us much information regarding the fertilization of pineapples. In Florida this crop is fertilized very heavily, but so far our planters have not used very large amounts. It is probable that complete fertilizers will be best, those containing large amounts of potash proving especially valuable in the latter stages of the growth, as the fruiting of the pine makes large drafts upon the potash contained in the soil. On many of our strongest soils the pineapple does not seem to require much fertilizing for the first crop, but it will doubtless prove very profitable for the second and third crops.

#### CONCLUSION.

It has been sought to throw some light on the question that comes to every planter in Porto Rico—whether it is best to use fertilizers. This is a question that he must answer largely for himself. The analysis of the soils is of very little use and is not worth the expense involved, save in exceptional cases. A better plan is to follow the scheme outlined of applying the fertilizer in different forms and amounts and having the soil give the answer. This can be done with little if any cost, as such trials well made will not only teach the planter the requirements of his soils, but will give him a profit from the beginning. Even if he should sustain a small loss at first, he will soon find how to turn this loss into a gain. He will learn not only a great deal about the capacity of his soils, but will know how to economically and very largely increase its productiveness and his resultant income.



